REMARKS

Claims 1, 3, 4, 6, 7, 9, 10, 12-14 and 15-21 are pending in the application and stand rejected. Claim 7 is herein amended. Claims 15-21 are herein added. In light of the following remarks, Applicant earnestly solicits favorable consideration.

On the Merits

Claim Rejections - 35 U.S.C. § 102(b)

Claims 1, 3, 4, 6, 7, 9, 10, 12-14 stand rejected under 35 U.S.C. §102(b) as being anticipated by "Mutual Adaptation in Human-Robot Cooperative Walk" by *Miyake*. Applicant respectfully traverses this rejection.

Independent claims 1 and 15:

The examiner has indicated as follows:

> Claim 1: A nonlinear controller (pg. 124, Introduction, right column, 2nd paragraph, lines 2-3) comprising: a first module (the oscillator system in figure 3, pg. 125) composed of a nonlinear system for creating a synchronous state (pg. 125, left column, 3rd paragraph lines 7-10 discusses the process of stabilization via synchronization of the system) with a controlled object through a nonlinear interaction with the controlled object and a second module (see claim interpretation) composed of a feedback system (pg. 125, observation part to the internal model from the oscillator) for adjusting a parameter to vary a relation value (human data values *i.e.*, figures 4-7, discussing the relation with the robotic time/phase values) of the first module (the oscillator system in figure 3, pg. 125) relating to the synchronization (pg. 125, left column, 3rd paragraph, lines 7-10 discusses the process of stabilization via synchronization of the system) with the controlled object based on the difference between the relation value (human data

> values *i.e.*, figures 4-7, discussing the relation with the robotic time/phase values), and a target relation value (target relation value *i.e.*, figures 4-7, discussing the relation with the robotic time/phase values) wherein the controlled object is controlled by convergence of the relation value (human data values *i.e.*, figures 4-7. discussing the relation with the robotic time/phase values) relating to the synchronization (pg.125, left column, 3rd paragraph, lines 7-10 discusses the process of stabilization via synchronization of the system) of the first module (the oscillator system in figure 3, pg.125) to the target relation value (target relation value *i.e.*, figures 4-7, discussing the relation with the robotic time/phase values), and the first module (the oscillator system in figure 3, pg.125) vibrates at different natural frequencies from the controlled object, and the nonlinear interaction has an entrainment effect (title with figure 3).

However the cited reference 1, *Miyake*, not only does not disclose the first feature of claim 1 or claim 15 but also does not disclose the second feature of claim 1 or claim 15 of the claimed invention.

The first feature of claim 1 is as follows:

> a second module composed of a feedback system for adjusting a parameter to vary a relation value of the first module relating to the synchronization with the controlled object based on the difference between the relation value and a target relation value.

The first feature of claim 15 is as follows:

> a second module composed of a feedback system (FBS) for adjusting a parameter of the first module to vary a relation value relating to the synchronization with the controlled object directly using the difference between the relation value and a target relation value in the nonlinear interaction in which dynamic behavior of a controller and a controlled object cannot be clearly separated.

This above feature is restrictive compared with the first feature of claim 1.

The second features of claim 1 and claim 15 are the same as follows:

> the controlled object is controlled by convergence of the relation value relating to the synchronization of the first module to the target relation value

These features could only be achieved by a substantial change in thinking from the conventional thinking.

Conventional control methods are characterized in that a controller unilaterally controls a controlled object on the basis that the dynamic behaviors of the controller and the controlled object are linearly—separable so that they may not mutually interfere. However, when there is a strong nonlinear interaction between the controller and controlled object, their dynamic behaviors cannot be separated and the controller cannot control the controlled object unilaterally. It has been conceived that control of a controlled object is difficult. However, more emphasis has been placed in recent years on a relationship and a dynamic interaction between an artificial object and a human, and the above nonlinear region in the machinery control can no longer be ignored.

In the conventional control methods, the controlled object and a controller have separated dynamic behaviors and are separately controlled.

The claimed invention proposes a new control method applicable to a situation having a strong nonlinearity. Specifically, the invention proposes a framework for a new control method which does not directly control a controlled object but controls a relation value through a nonlinear interaction between the controlled object and a controller on the basis of a dynamic relationship created in the nonlinear interaction. This is referred to as the "relational system control method."

In this method, the dynamic behaviors of the controller and the controlled object are no longer separated for controlling as in the conventional thought, and the dynamic relationship between the controlled object and the controller is controlled instead of the controlled object

itself without separating the dynamic behaviors. Applicant respectfully submits that such an idea could only be reached after conducting extensive research that suggests it is essentially impossible to control with such a model separating the dynamic behaviors as all of the conventional models. Thus, it will be impossible to arrive at the claimed invention based on any conventional model. The "relational system control method" for controlling such a nonlinear system was a groundbreaking proposal at the time of filing.

In the description when the application was filed, the sentence "The controller 1 constituted of two modules: a first module 3 as a nonlinear system and a second module 4 as a feedback system, and the controlled object 2 is controlled according to feedback from the second module 4 to the first module 3, which forms a synchronous state with the controlled object 2 through a nonlinear interaction, so as to converge a relation value 5 relating to the synchronization with the controlled object 2 to a target relation value. That is, a "relational system control method" is applied as a method for controlling a nonlinear system." is described. (See the paragraph [0027].)

The "relational system control method" includes (a) focusing on a nonlinear interaction such as entrainment between rhythms, and self-organizing a dynamic relationship between a controller and a controlled object (*e.g.*, a relationship such as a phase relationship according to synchronization); and (b) controlling the relationship itself (relation value) so as to converge the relationship toward a target relationship (target relation value) based on the self-organized dynamic relationship. In order to realize the above, the invention according to the claims proposes a hierarchical nonlinear controller that comprises: (a) a first module for achieving a

synchronous state with the controlled object through the nonlinear interaction; and (b) a second module for performing feedback to converge a relation value, which is related to the synchronization with the controlled object, to a target value.

Conventional arts utilizing a nonlinearity are grouped into three groups, (Al) Simple synchronization model 1, (A2) Simple synchronization model 2 and (B) Co-creation model.

(Al) Simple synchronization model

MIYAKE Y ET AL :"Mutual entrainment based human-robot communication field-paradigm shift from human interface to communication field" ROBOT AND HUMAN INTERACTIVE COMMUNICATION, 1994, RO-MAN '94, NAGOYA, PROCEEDINGS. 3rd IEEE INTERNATIONAL WORKSHOP ON NAGOYA, JAPAN 18-20 July 1994, pages 118-123 (cited reference D3 in EP examination).

YUASA H ET AL: "COORDINATION OF MANY OSCILLATORS AND GENERATION OF LOCOMOTORY PATTERNS" BIOLOGICAL CYBERNETICS, SPRINGER VERLAG. HEIDELBERG, DE, vol.63, no.3, 1 July 1990 (1990 07-01), pages 177-184 (cited reference D6 in EP examination, cited reference in US examination too).

(A2) Simple synchronization model 2

MIYAKE Y ET AL: "Mutual adaptation in human-robot cooperative walk-mutual-entrainment-based internal control" ROBOT AND HUMAN COMMUNICATION, 1997. RO-MAN '97. PROCEEDINGS. 6th IEEE INTERNATIONAL WORKSHOP ON SENDA, JAPAN 29 SEPT. - 1 OCT. 1997, pages 124—129. (cited reference D5 in EP examination).

It is the cited reference under 35. U.S.C. § 102 (b) It is referred as cited reference 1 hereinafter.

(B) Co—creation model.

MUTO AND MIYAKE 2002, "Analysis of the Co-emergence Process on the Human-Robot Cooperation for Walk-support" the Society of Instrument and Control Engineers, vol.38, No.3, p. 2002 (cited reference in JP examination).

MIYAKE Y ET AL: "Internal observation and mutual adaptation in human-robot cooperation" SYSTEMS MAN AND CYBERNETICS, 1998, 1998 IEEE INTERNATIONAL CONFERENCE ON SAN DIEGO, CA, USA 11-14 OCT. 1998, pages 3685—3690 (cited reference Dl in EP examination).

MUTO AND MIYAKE: "Analysis of the co-emergence process on the human-human cooperation" ROBOT AND HUMAN INTERACTIVE COMMUNICATION, 2002, PROCEEDINGS. 11 IEEE INTERNATIONAL WORKSHOP ON SEPT. 25-27, 2002 (cited reference D2 in EP examination).

MUTO AND MIYAKE: "Analysis of the process of mutual interaction between human and internal control model" IEEE 2000 pages 769—774 (cited reference in US examination).

As described above, the inventor of the subject application has been deeply involved in the majority of the prior art, and in fact has taken a pioneering role in the field of nonlinear control.

(Al) Simple synchronization model 1 has the function of achieving a synchronous state with the controlled object through the nonlinear interaction by using entrainment as in the first

module but not the function of controlling as in the second module. Only the above (a) may be realized but not a controlling part corresponding to the above (b). In other words, although self-organization or the entrainment is used, it remains as a model that establishes simple synchronization with the controlled object and a method for controlling a resulting relationship is not taken into consideration.

(A2) Simple synchronization model 2 has a vibration system corresponding to the first module. Although it appears to include an internal model corresponding to a module 2 in addition to the vibration system, the internal model is hypothetical model showing a possibility for controlling a nonlinear system but not showing how to realize such controlling. The model still remains as a simple synchronization model.

In the above document (cited reference 1), there is no target relation value and there is no feedback control mechanism as recited in claims 1 and 15. A possibility for approaching the control of the relationship in a nonlinear interaction using a period is suggested in the Fig. 3 and Fig. 10 in the above document (cited reference 1), but it is not apparent what kind of period should be given. The only thing that has been eventually realized is to enhance the synchrony between the robot and the human (the walking person) to synchronize a period and timing.

Even though the title of section 3.2 in the cited reference 1 is the "Control of relationship" and it is described in the section that the phase difference changes depending on the difference between the original period of the robot and the human, what is realized as a result in the section is a simple synchronized state such as synchronization with no phase difference between the robot and the walking person. Figures 4-7 in the cited reference 1 show only that the

robot and the walking person synchronize the period and timing. Although controlling needs any target value, the period of the robot, the period of the walking person and the phase difference between the robot and the walking person are not controlled to any target value. Namely a target value is not found in human data of figures 4-7 or anywhere in the cited reference 1. And although controlling needs to adjust a value of a specific parameter toward a voluntary target value, the period and timing are only synchronized but are not adjusted or controlled toward a voluntary target value. Further the cited reference 1 does not show how to adjust the period of such a nonlinear oscillating system based on Fig. 10.

The internal model in the cited reference 1 has a "feedback loop" through observation and action but it is just a "feedback loop" which realizes a synchronized state as mentioned above but can not adjust a value of a specific parameter toward a voluntary target value. Therefore the model shown in Fig. 3 can not control the synchronous relationship available and is not a "control system" as recited in the claimed invention. Namely the internal model has no feedback control mechanism for adjusting a parameter to vary a relation value of the first module. Further the internal model does not create any concrete feedback control value relating to the synchronization with its environment. Further, the observation part is not the feedback system since observation is not conducted between an internal model and the oscillator, but is conducted between system and environment as shown in Fig. 3.

Therefore the first features of claim 1 and claim 15 are not disclosed in the cited reference 1. Further, the second features of claim 1 and claim 15 are also not disclosed in the cited reference 1.

As for (B) Co-creation model, an attempt in order to control a synchronous relationship was made to advance from a simple synchronous model. To overcome the problems remaining in simple synchronization models 1 and 2, a module 2 (Internal Model) was added for controlling the relationship created in the module 1 (Body Model) to construct a co-creation model as a hierarchical control system. For the purpose of controlling the synchronous relationship generated between a body model (corresponding to the first module) and the controlled object, the inventor introduced a target relation value (*e.g.*, phase relationship θ_d in D2, $\Delta \o_d$ in Dl) in the module 2 and tried to make a control process in the internal model specifically and proposed a mechanism thereof.

In the conventional control methods, the controlled object and a controller have separated dynamic behaviors and are separately controlled. Any solution to resolve dynamic behavior of nonlinear interaction has not been found yet. Therefore, it seems a natural consequence and reliable that a possible control mechanism for the internal model is searched by separating a nonlinear interaction into two unidirectional actions. A dynamic behavior of unidirectional action has been analyzed usually in the conventional control methods. Considering the above, the inventor has proposed a co-creation model described below to obtain the solution for controlling the nonlinear interaction, but has consequently found that it is essentially impossible to implement control by this model.

As shown in Fig. 1 of Dl or D2 (please refer Fig.1 in D2 or Dl cited reference in EP examination), an attempt was made with the co-creation model such that two internal states on the machine side and the human side (*e.g.*, natural frequencies ω_m and ω_h in D2, ω_r and ω_h in Dl)

in an internal model are estimated from a relation value (*e.g.*, a phase relationship θ_{HM} in D2, Δ_{HR} in Dl) in the nonlinear interaction with the body model and feedback control is tried on the basis of the two internal states so as to converge the relation value relating to the synchronization to a target relation value.

In this model, an attempt was made to estimate the internal states of the self (machine side) and the other (human side) by separating the nonlinear interaction into two unidirectional actions. However, as a result of analysis of the co-creation model, the inventor has found that the relation value cannot be essentially controlled with this model because an inseparable nonlinear interaction between the controller and controlled object causes ill-posedness. A situation in which the amount of estimated information (ω_m and ω_h herein) is greater than the amount of input information (θ_{HM} herein) is referred to as "ill-posedness", and due to this ill-posedness, the solution cannot be uniquely determined. Accordingly, convergence to the target value is not ensured and the inventor has found that the relation value cannot be essentially controlled with this model.

Accordingly, the relationship between the construction of the model itself and the calculations performed therein becomes self-referential, thereby unable to establish its validity. Therefore, the internal model is merely a hypothetical model, and there are no guarantees that the process of estimating the physical motions of the self and the other based on the internal model corresponds to the actual physical motions. In other words, there is no guarantee that ω_m and θ_{hm} representing the state of the internal model corresponds to ω_M (ω_M in D2, ω_R in Dl) and θ_{HM} representing the state of the physical model. Thus, calculations performed in the internal model

cannot be referred to as "control." What is performed therein are endless invalid calculations, Conversely, it may create an unexpected new motion. This is the feature of co-creative dynamics.

Comparing the communication model proposed in the cited reference D2 or Dl with the invention according to the claims, both the communication model and the claimed invention create a dynamic relationship through entrainment. However, the internal model cannot control the dynamic relationship of entrainment due to the above self-reference process. Conversely, the inability to control generates an unexpected new motion, and such a motion is referred to as "creation" or "co-creation". As apparent from the above, the model proposed in the cited reference D2 or D1 insists that the nature of communication resides in the inability to control.

On the other hand, the claimed invention fundamentally differs from the above and proposes a control method. As apparent from being named a "relational system control method," the proposed method focuses on a relationship created through an interaction and aims to control the relationship as it is.

The claimed invention does not separate the relationship into the own side and the other side, but maintains the relationship as it is and performs feedback control on it. This ensures the novelty of the invention that could only be achieved by the substantial change in thinking, and consequently allows control in a nonlinear system. Accordingly, control of the relationship as described above allows control toward a predetermined target value, for example, by decelerating a walking tempo of on unaffected leg of a hemiplegic patient while accelerating the walking tempo of an affected leg so that the walking speeds approach a targeted equal tempo.

As instructed previously, reference 1 does not disclose a target relation value and a feedback control system as recited in claim 1 and 15.

Further, as described above, the claimed invention recites "relational system control method" is achieved from recognition of inseparability of the dynamic behaviors between the controller and controlled object in the nonlinear system and an aim to propose a new controller and a control method with which an inseparable relationship between the controller and controlled object can be converged into a target relationship.

With the above recognition and for the above purposes, the roles of the first module and the second module are clearly separated such that the first module is composed of a nonlinear system for achieving a synchronous state with a controlled object through a nonlinear interaction with the controlled object and the second module is composed of a feedback system for adjusting a parameter of the first module for changing a relation value relating to synchronization with the second module. Accordingly, the first module conducts the actual interaction with the controlled object while the second module performs adjustment to change the relation value.

The inventor eventually reached the claimed invention with substantial change in thinking based on the above recognition. As described above, the claimed invention could not be easily achieved from the cited reference 1.

As such, applicant respectfully asks that the examiner withdraw the rejection and allow the application.

New Claim 16

Claim 16 depends on claim 15 and could not be easily achieved since claim 15 could not be easily achieved. Therefore Claim 16 should also be allowed.

Furthermore, the third feature of claim 16 is as follows:

> the first module calculates the relation value using a state variable of the controlled object and equations approximating the dynamics of the controlled object and the first module as nonlinear vibrations.

The relation value is not calculated in the second module as in a conventional model (B) but is calculated in the first module in the claimed invention. Calculation of the relation value is not disclosed in conventional model (A1) or (A2). In the claimed invention, the first module achieves a synchronous state with the controlled object through a nonlinear interaction with the controlled object. That is, a state variable of the controlled object is obtained through the actual interaction, and the relation value is calculated. Thus, this calculation reflects the actual interaction. Through the calculation, a new phase of the first module is outputted to the controlled object and affects the controlled object.

Then, the state variable of the controlled object affected by the above is inputted into the first module. The state variable of the controlled object is affected through the calculation in the first module as described above. However, due to nonlinearity of the controlled object the dynamic behavior of the controlled object does not always follow the above equation and may act unexpectedly. Accordingly, the first module can directly reflect the actual interaction in the calculation of the relation value only by continuously obtaining the state variable of the controlled object through the actual interaction.

In contrast, in the cited reference D2 or Dl (Please refer D2 or Dl cited reference in EP examination) calculations are performed in the internal model. The internal model has no foundation to determine whether it is suitable as a body notion model of its awn and the other, Since a relationship between the construction of the model and the calculations performed therein becomes self-referential, the validity of the internal model cannot be determined.

Accordingly, the internal model is merely a hypothetical model, and there is no guarantee that the process of estimating the body motions of its own and the other based on the internal model corresponds to the actual body motions. Thus, the calculations performed in the internal model cannot be referred to as "control." In other words, the third feature has its purpose in nonlinear control, and based on the recognition of a result such that the relation value cannot be controlled by the approximation using the conventional method with which the dynamic behaviors of the controller and the controlled object are separated, the third feature could only be achieved by the "relational system control method" created through a substantial change in thinking. Therefore, it could not be easily conceived from the cited reference 1, D2 or D1.

Further, the fourth feature of claim 16 is as follows:

> the second module calculates a feedback control signal (FB) as a function relating to a difference between the calculated relation value and the target relation value and adjusts the parameter of the first module using the feedback control signal (FB).

The feedback control signal FB is not disclosed in any conventional method. The feedback control signal FB is specifically defined (in the paragraphs [0039], [0040] as a function of a difference between the calculated relational value and the target relational value. The

amount of feedback can also be adjusted by varying the coefficient k3 representing the feedback control signal FB (equation 3).

In contrast, in the cited reference D2 or Dl the characteristic frequency ω_m (ω_m in D2, ω_r in Dl) of the model is sought and the characteristic frequency ω_M (ω_M in D2, ω_R in Dl) of the body model is restrained. However, only the characteristic frequency ω_M as a parameter is disclosed, but not the idea to adjust the characteristic frequency as a parameter with the feedback control signal that differs from the characteristic frequency. Thus, the technical idea to adjust the characteristic frequency as a parameter with the feedback control signal is not disclosed in the conventional nonlinear control methods containing reference 1, D2, Dl. Further, a specific feedback function is not disclosed either.

As described so far, representation of the specific feedback control signal FB as the function of the difference between the relation value and the target relation value in the claims is a progress to practically realize the nonlinear control and introduces a new technological idea. Therefore, the fourth feature is made possible by the new technological idea, and thus it could not be easily conceived on the basis of what is described in the cited reference 1, D2 or Dl.

As described so far, the third feature and the fourth features of claim 16 are not described in the cited reference1. As such, applicant respectfully submits that claim 16 is presently in condition for allowance.

New Claim 20

Claim 20 is related to Nonlinear Control Method corresponding to Nonlinear Controller which is claimed as claim 15. Thus, the same arguments as recited above with respect to claim 15 also apply to claim 20.

As such, applicant respectfully submits that claim 20 is presently in condition for allowance.

In view of the aforementioned amendments and accompanying remarks, Applicants submit that the claims, as herein amended, are in condition for allowance. Applicants request such action at an early date.

If the Examiner believes that this application is not now in condition for allowance, the Examiner is requested to contact Applicants' undersigned attorney to arrange for an interview to expedite the disposition of this case.

If this paper is not timely filed, Applicants respectfully petition for an appropriate extension of time. The fees for such an extension or any other fees that may be due with respect to this paper may be charged to Deposit Account No. 50-2866.

Respectfully submitted,

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